

## **Appendix B-1**

**Simply supported square plate. 1/4 sym. Plate overall dimensions 2" X 2"  
QUAD4 is MIN4T element**

**Plate thickness 0.02" (thin)**

Table B1-1

Convergence study - increasing mesh size  
Thin plate: 0.02", Uniform pressure load 0.05 psi

**Central point lateral displacement: theoretical = 4.070E-04 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	4.177474E-04	2.6%	3.882019E-04	-4.6%	4.053825E-04	-0.4%	4.064101E-04	-0.1%
5	4.089617E-04	0.5%	4.044364E-04	-0.6%	4.069221E-04	0.0%	4.072906E-04	0.1%
10	4.076979E-04	0.2%	4.066298E-04	-0.1%	4.070296E-04	0.0%	4.071537E-04	0.0%
20	4.073804E-04	0.1%	4.071399E-04	0.0%	4.070529E-04	0.0%	4.070879E-04	0.0%
50	4.072894E-04	0.1%	4.072582E-04	0.1%	4.070591E-04	0.0%	4.070651E-04	0.0%
100	4.072759E-04	0.1%	4.072688E-04	0.1%	4.070600E-04	0.0%	4.070615E-04	0.0%
200			4.072707E-04	0.1%	4.070602E-04	0.0%	4.070605E-04	0.0%

**Max x or y bending moment: theoretical = -9.577E-03 lb-in/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-8.041848E-03	-16.0%	-8.251984E-03	-13.8%	-7.932362E-03	-17.2%	-7.980317E-03	-16.7%
5	-9.329311E-03	-2.6%	-9.402860E-03	-1.8%	-9.316309E-03	-2.7%	-9.326607E-03	-2.6%
10	-9.516958E-03	-0.6%	-9.538238E-03	-0.4%	-9.513549E-03	-0.7%	-9.514432E-03	-0.7%
20	-9.563905E-03	-0.1%	-9.568613E-03	-0.1%	-9.562834E-03	-0.1%	-9.562405E-03	-0.2%
50	-9.576865E-03	0.0%	-9.577013E-03	0.0%	-9.576632E-03	0.0%	-9.576411E-03	0.0%
100	-9.578667E-03	0.0%	-9.578567E-03	0.0%	-9.578603E-03	0.0%	-9.578518E-03	0.0%
200			-9.579062E-03	0.0%	-9.579095E-03	0.0%	-9.579065E-03	0.0%

**Max twisting moment: theoretical = -6.496E-03 lb-in/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-4.642756E-03	-28.5%	-4.423924E-03	-31.9%	-4.823450E-03	-25.7%	-4.763773E-03	-26.7%
5	-6.039231E-03	-7.0%	-6.069230E-03	-6.6%	-6.075395E-03	-6.5%	-6.067006E-03	-6.6%
10	-6.350917E-03	-2.2%	-6.381598E-03	-1.8%	-6.360069E-03	-2.1%	-6.360019E-03	-2.1%
20	-6.451331E-03	-0.7%	-6.466028E-03	-0.5%	-6.453200E-03	-0.7%	-6.454149E-03	-0.6%
50	-6.485836E-03	-0.2%	-6.489589E-03	-0.1%	-6.485967E-03	-0.2%	-6.486422E-03	-0.1%
100	-6.491724E-03	-0.1%	-6.492906E-03	0.0%	-6.491745E-03	-0.1%	-6.491934E-03	-0.1%
200			-6.493751E-03	0.0%	-6.493411E-03	0.0%	-6.493480E-03	0.0%

**Max x or y transverse shear: theoretical = -3.375E-02 lb/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-2.120397E-02	-37.2%	-2.355221E-02	-30.2%				
5	-2.873378E-02	-14.9%	-2.980993E-02	-11.7%				
10	-3.125650E-02	-7.4%	-3.210377E-02	-4.9%				
20	-3.251324E-02	-3.7%	-3.310807E-02	-1.9%				
50	-3.326562E-02	-1.4%	-3.343383E-02	-0.9%				
100	-3.351608E-02	-0.7%	-3.356282E-02	-0.6%				
200			-3.366052E-02	-0.3%				

Table B1-2

Random disorder of element shape - mesh size is 10 x 10  
Thin plate: 0.02", Uniform pressure load 0.05 psi

**Central point lateral displacement: theoretical = 4.070E-04 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	4.076979E-04	0.2%	4.066298E-04	-0.1%	4.070296E-04	0.0%	4.071537E-04	0.0%
0.1	4.076845E-04	0.2%	4.065895E-04	-0.1%	4.069936E-04	0.0%	4.070827E-04	0.0%
0.2	4.076601E-04	0.2%	4.065019E-04	-0.1%	4.069458E-04	0.0%	4.069921E-04	0.0%
0.3	4.076150E-04	0.2%	4.063725E-04	-0.2%	4.068937E-04	0.0%	4.069003E-04	0.0%
0.4	4.075636E-04	0.1%	4.062242E-04	-0.2%	4.068626E-04	0.0%	4.067432E-04	-0.1%
0.5	4.075042E-04	0.1%	4.059689E-04	-0.3%	4.067344E-04	-0.1%	4.066651E-04	-0.1%
0.6	4.074408E-04	0.1%	4.053971E-04	-0.4%	4.066827E-04	-0.1%	4.066200E-04	-0.1%
0.7			4.052982E-04	-0.4%			4.063957E-04	-0.1%
0.8			4.046979E-04	-0.6%			4.062411E-04	-0.2%

**Max x or y bending moment: theoretical = -9.577E-03 lb-in/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-9.516958E-03	-0.6%	-9.538238E-03	-0.4%	-9.513549E-03	-0.7%	-9.514432E-03	-0.7%
0.1	-9.508684E-03	-0.7%	-9.531171E-03	-0.5%	-9.511662E-03	-0.7%	-9.508362E-03	-0.7%
0.2	-9.513518E-03	-0.7%	-9.540563E-03	-0.4%	-9.497620E-03	-0.8%	-9.497151E-03	-0.8%
0.3	-9.498255E-03	-0.8%	-9.528532E-03	-0.5%	-9.509454E-03	-0.7%	-9.505900E-03	-0.7%
0.4	-9.508094E-03	-0.7%	-9.518584E-03	-0.6%	-9.488904E-03	-0.9%	-9.480915E-03	-1.0%
0.5	-9.475692E-03	-1.1%	-9.503319E-03	-0.8%	-9.471925E-03	-1.1%	-9.481681E-03	-1.0%
0.6	-9.510552E-03	-0.7%	-9.467728E-03	-1.1%	-9.462858E-03	-1.2%	-9.453775E-03	-1.3%
0.7			-9.503531E-03	-0.8%			-9.486368E-03	-0.9%
0.8			-9.454101E-03	-1.3%			-9.485915E-03	-1.0%

**Max twisting moment: theoretical = -6.496E-03 lb-in/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-6.350917E-03	-2.2%	-6.381598E-03	-1.8%	-6.360069E-03	-2.1%	-6.360019E-03	-2.1%
0.1	-6.355576E-03	-2.2%	-6.378455E-03	-1.8%	-6.361073E-03	-2.1%	-6.361410E-03	-2.1%
0.2	-6.350873E-03	-2.2%	-6.390043E-03	-1.6%	-6.370030E-03	-1.9%	-6.377284E-03	-1.8%
0.3	-6.308518E-03	-2.9%	-6.420099E-03	-1.2%	-6.359695E-03	-2.1%	-6.375967E-03	-1.8%
0.4	-6.350845E-03	-2.2%	-6.463871E-03	-0.5%	-6.340293E-03	-2.4%	-6.381823E-03	-1.8%
0.5	-6.370382E-03	-1.9%	-6.409916E-03	-1.3%	-6.366337E-03	-2.0%	-6.401488E-03	-1.5%
0.6	-6.220156E-03	-4.2%	-6.496164E-03	0.0%	-6.357278E-03	-2.1%	-6.390720E-03	-1.6%
0.7			-6.462622E-03	-0.5%			-6.371801E-03	-1.9%
0.8			-6.179344E-03	3.4%			-6.332287E-03	-2.5%

**Max x or y transverse shear: theoretical = -3.375E-02 lb/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-3.125650E-02	-7.4%	-3.230785E-02	-4.3%				
0.1	-3.137727E-02	-7.0%	-3.249074E-02	-3.7%				
0.2	-3.131193E-02	-7.2%	-3.328399E-02	-1.4%				
0.3	-3.227968E-02	-4.4%	-3.352161E-02	-0.7%				
0.4	-3.253596E-02	-3.6%	-3.592427E-02	6.4%				
0.5	-3.573537E-02	5.9%	-3.431050E-02	1.7%				
0.6	-3.739516E-02	10.8%	-3.296402E-02	-2.3%				
0.7			-3.407969E-02	1.0%				
0.8			-3.609102E-02	6.9%				

**Note 1:** Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

## **Appendix B-2**

**Simply supported square plate. 1/4 sym. Plate overall dimensions 2" X 2"  
QUAD4 is MIN4T element**

**Plate thickness 0.20" (thick)**

Table B2-1

Convergence study - increasing mesh size  
Thick plate: 0.20", Uniform pressure load 0.05 psi

**Central point lateral displacement: theoretical = 4.294E-07 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	4.395387E-07	2.4%	4.146006E-07	-3.4%	4.053825E-07	-5.6%	4.064101E-07	-5.4%
5	4.300534E-07	0.2%	4.270713E-07	-0.5%	4.069221E-07	-5.2%	4.072906E-07	-5.1%
10	4.286389E-07	-0.2%	4.280076E-07	-0.3%	4.070296E-07	-5.2%	4.071537E-07	-5.2%
20	4.282798E-07	-0.3%	4.281360E-07	-0.3%	4.070529E-07	-5.2%	4.070879E-07	-5.2%
50	4.281788E-07	-0.3%	4.281575E-07	-0.3%	4.070591E-07	-5.2%	4.070651E-07	-5.2%
100	4.281643E-07	-0.3%	4.281593E-07	-0.3%	4.070600E-07	-5.2%	4.070615E-07	-5.2%
200			4.281595E-07	-0.3%	4.070602E-07	-5.2%	4.070606E-07	-5.2%

**Max x or y bending moment: theoretical = -9.607E-03 lb-in/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-8.074155E-03	-16.0%	-8.286672E-03	-13.7%	-7.932362E-03	-17.4%	-7.980317E-03	-16.9%
5	-9.340636E-03	-2.8%	-9.384681E-03	-2.3%	-9.316309E-03	-3.0%	-9.326607E-03	-2.9%
10	-9.520004E-03	-0.9%	-9.522622E-03	-0.9%	-9.513549E-03	-1.0%	-9.514432E-03	-1.0%
20	-9.564479E-03	-0.4%	-9.562965E-03	-0.5%	-9.562834E-03	-0.5%	-9.562405E-03	-0.5%
50	-9.576896E-03	-0.3%	-9.576334E-03	-0.3%	-9.576632E-03	-0.3%	-9.576411E-03	-0.3%
100	-9.578669E-03	-0.3%	-9.578481E-03	-0.3%	-9.578603E-03	-0.3%	-9.578518E-03	-0.3%
200			-9.579054E-03	-0.3%	-9.579094E-03	-0.3%	-9.579056E-03	-0.3%

**Max twisting moment: theoretical = -6.225E-03 lb-in/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-4.668448E-03	-25.0%	-4.500427E-03	-27.7%	-4.823450E-03	-22.5%	-4.763773E-03	-23.5%
5	-6.052187E-03	-2.8%	-6.089201E-03	-2.2%	-6.075395E-03	-2.4%	-6.067006E-03	-2.5%
10	-6.354222E-03	2.1%	-6.379003E-03	2.5%	-6.360069E-03	2.2%	-6.360019E-03	2.2%
20	-6.451367E-03	3.6%	-6.461321E-03	3.8%	-6.453200E-03	3.7%	-6.454149E-03	3.7%
50	-6.485563E-03	4.2%	-6.487857E-03	4.2%	-6.485967E-03	4.2%	-6.486422E-03	4.2%
100	-6.491641E-03	4.3%	-6.492338E-03	4.3%	-6.491745E-03	4.3%	-6.491934E-03	4.3%
200			-6.493610E-03	4.3%	-6.493411E-03	4.3%	-6.493481E-03	4.3%

**Max x or y transverse shear: theoretical = -3.374E-02 lb/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-2.112100E-02	-37.4%	-2.338886E-02	-30.7%				
5	-2.870941E-02	-14.9%	-2.916144E-02	-13.6%				
10	-3.125004E-02	-7.4%	-3.133337E-02	-7.1%				
20	-3.251203E-02	-3.6%	-3.252939E-02	-3.6%				
50	-3.326553E-02	-1.4%	-3.327051E-02	-1.4%				
100	-3.351604E-02	-0.7%	-3.351810E-02	-0.7%				
200			-3.364134E-02	-0.3%				

**Note 1:** Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Table B2-2

Random disorder of element shape - mesh size is 10 x 10  
Thick plate: 0.20", Uniform pressure load 0.05 psi

**Central point lateral displacement: theoretical = 4.294E-07 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	4.286389E-07	-0.2%	4.280076E-07	-0.3%	4.070296E-07	-5.2%	4.071537E-07	-5.2%
0.1	4.286363E-07	-0.2%	4.279977E-07	-0.3%	4.069889E-07	-5.2%	4.070835E-07	-5.2%
0.2	4.286255E-07	-0.2%	4.279538E-07	-0.3%	4.069567E-07	-5.2%	4.069980E-07	-5.2%
0.3	4.286026E-07	-0.2%	4.278728E-07	-0.4%	4.069297E-07	-5.2%	4.069015E-07	-5.2%
0.4	4.285964E-07	-0.2%	4.277729E-07	-0.4%	4.068571E-07	-5.2%	4.067849E-07	-5.3%
0.5	4.285648E-07	-0.2%	4.277427E-07	-0.4%	4.06887E-07	-5.3%	4.067714E-07	-5.3%
0.6	4.285039E-07	-0.2%	4.274602E-07	-0.5%	See Note 1		4.066252E-07	-5.3%
0.7	4.284351E-07	-0.2%	4.272412E-07	-0.5%	4.063414E-07	-5.4%	4.063621E-07	-5.4%
0.8	See Note 1		4.273250E-07	-0.5%	See Note 1		4.062954E-07	-5.4%

**Max x or y bending moment: theoretical = -9.607E-03 lb-in/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-9.520004E-03	-0.9%	-9.522622E-03	-0.9%	-9.513549E-03	-1.0%	-9.514432E-03	-1.0%
0.1	-9.516887E-03	-0.9%	-9.516944E-03	-0.9%	-9.508573E-03	-1.0%	-9.509657E-03	-1.0%
0.2	-9.515005E-03	-1.0%	-9.513496E-03	-1.0%	-9.500159E-03	-1.1%	-9.497733E-03	-1.1%
0.3	-9.510936E-03	-1.0%	-9.510518E-03	-1.0%	-9.497190E-03	-1.1%	-9.498315E-03	-1.1%
0.4	-9.503080E-03	-1.1%	-9.502445E-03	-1.1%	-9.492558E-03	-1.2%	-9.484133E-03	-1.3%
0.5	-9.495133E-03	-1.2%	-9.499946E-03	-1.1%	-9.468693E-03	-1.4%	-9.478471E-03	-1.3%
0.6	-9.485838E-03	-1.3%	-9.482645E-03	-1.3%	See Note 1		-9.475569E-03	-1.4%
0.7	-9.523367E-03	-0.9%	-9.482962E-03	-1.3%	-9.479518E-03	-1.3%	-9.450705E-03	-1.6%
0.8	See Note 1		-9.488444E-03	-1.2%	See Note 1		-9.472364E-03	-1.4%

**Max twisting moment: theoretical = -6.225E-03 lb-in/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-6.354222E-03	2.1%	-6.379003E-03	2.5%	-6.360069E-03	2.2%	-6.360019E-03	2.2%
0.1	-6.358936E-03	2.2%	-6.386316E-03	2.6%	-6.363487E-03	2.2%	-6.360086E-03	2.2%
0.2	-6.377200E-03	2.4%	-6.398629E-03	2.8%	-6.367205E-03	2.3%	-6.367530E-03	2.3%
0.3	-6.335701E-03	1.8%	-6.390431E-03	2.7%	-6.347635E-03	2.0%	-6.389979E-03	2.7%
0.4	-6.359404E-03	2.2%	-6.433151E-03	3.3%	-6.361833E-03	2.2%	-6.356812E-03	2.1%
0.5	-6.337010E-03	1.8%	-6.424353E-03	3.2%	-6.375497E-03	2.4%	-6.376842E-03	2.4%
0.6	-6.323262E-03	1.6%	-6.421069E-03	3.1%	See Note 1		-6.386909E-03	2.6%
0.7	-6.361620E-03	2.2%	-6.419936E-03	3.1%	-6.329188E-03	1.7%	-6.416808E-03	3.1%
0.8	See Note 1		-6.458207E-03	3.7%	See Note 1		-6.414755E-03	3.0%

**Max x or y transverse shear: theoretical = -3.375E-02 lb/in**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-3.125004E-02	-7.4%	-3.133337E-02	-7.2%				
0.1	-3.131184E-02	-7.2%	-3.132976E-02	-7.2%				
0.2	-3.129734E-02	-7.3%	-3.136309E-02	-7.1%				
0.3	-3.129752E-02	-7.3%	-3.139836E-02	-7.0%				
0.4	-3.133671E-02	-7.2%	-3.125302E-02	-7.4%				
0.5	-3.128780E-02	-7.3%	-3.130338E-02	-7.2%				
0.6	-3.120514E-02	-7.5%	-3.098793E-02	-8.2%				
0.7	-3.094243E-02	-8.3%	-3.154259E-02	-6.5%				
0.8	See Note 1		-3.127497E-02	-7.3%				

**Note 1:** Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

)

### **Appendix B-3**

**Square plate supported only at the central point. 1/4 sym.**

**Plate overall dimensions 2" X 2"**

**QUAD4 is MIN4T element**

**Plate thickness 0.02" (thin)**

Table B3-1

Convergence study - increasing mesh size  
Thin plate: 0.02", stress free thermal expansion - 1.0 deg bulk temperature change

**Central point lateral displacement: theoretical = 2.000E-05 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
5	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
10	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
20	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
50	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
100	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
200	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%

**Max stress: theoretical = 0 lb/in^2**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	E-13		E-13		E-13		E-13	
5	E-13		E-12		E-12		E-12	
10	E-12		E-12		E-12		E-12	
20	E-12		E-12		E-12		E-12	
50	E-11		E-11		E-11		E-11	
100	E-10		E-10		E-10		E-10	
200			E-10		E-09		E-10	



Table B3-2

Random disorder of element shape - mesh size is 10 x 10  
Thin plate: 0.02", stress free thermal expansion - 1.0 deg bulk temperature change

**Central point lateral displacement: theoretical = 2.000E-05 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.1	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.2	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.3	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.4	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.5	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.6	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.7	2.000000E-05	0.0%	2.000000E-05	0.0%	See Note 1		2.000000E-05	0.0%
0.8	See Note 1		2.000000E-05	0.0%	See Note 1		2.000000E-05	0.0%

**Max stress: theoretical = 0 lb/in^2**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	E-12		E-12		E-12		E-12	
0.1	E-12		E-12		E-12		E-12	
0.2	E-12		E-12		E-12		E-12	
0.3	E-12		E-12		E-12		E-12	
0.4	E-12		E-12		E-12		E-12	
0.5	E-12		E-12		E-12		E-12	
0.6	E-12		E-12		E-11		E-12	
0.7	E-12		E-12		See Note 1		E-12	
0.8	See Note 1		E-12		See Note 1		E-11	

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Table B3-3

Convergence study - increasing mesh size

Thin plate: 0.02", stress free thermal expansion - 1.0 deg temperature gradient through thickness

**Central point lateral displacement: theoretical = -2.000E-05 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
5	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
10	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
20	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
50	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
100	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
200	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-1.999998E-05	0.0%

**Max stress: theoretical = 0 lb/in^2**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	E-13		E-13		E-14		E-14	
5	E-12		E-12		E-12		E-13	
10	E-11		E-11		E-11		E-12	
20	E-10		E-11		E-09		E-09	
50	E-09		E-08		E-08		E-08	
100	E-07		E-09		E-08		E-06	
200			E-08		E-06		E-05	

Table B3-4

Random disorder of element shape - mesh size is 10 x 10

Thin plate: 0.02", stress free thermal expansion - 1.0 deg temperature gradient through thickness

**Central point lateral displacement: theoretical = -2.000E-05 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.1	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.2	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.3	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.4	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.5	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.6	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.7	-2.000000E-05	0.0%	-2.000000E-05	0.0%	See Note 1		-2.000000E-05	0.0%
0.8	See Note 1		-2.000000E-05	0.0%	See Note 1		-2.000000E-05	0.0%

**Max stress: theoretical = 0 lb/in^2**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	E-11		E-11		E-11		E-12	
0.1	E-12		E-11		E-11		E-11	
0.2	E-12		E-11		E-11		E-11	
0.3	E-11		E-11		E-11		E-11	
0.4	E-11		E-11		E-11		E-12	
0.5	E-11		E-11		E-11		E-11	
0.6	E-10		E-11		E-11		E-11	
0.7	E-11		E-11		See Note 1		E-11	
0.8	See Note 1		E-11		See Note 1		E-02	

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

## **Appendix B-4**

**Square plate supported only at the central point. 1/4 sym.**

**Plate overall dimensions 2" X 2"**

**QUAD4 is MIN4T element**

**Plate thickness 0.20" (thick)**

Table B4-1

Convergence study - increasing mesh size  
 Thick plate: 0.20", stress free thermal expansion - 1.0 deg bulk temperature change

**Central point lateral displacement: theoretical = 2.000E-05 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
5	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
10	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
20	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
50	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
100	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
200	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%

**Max stress: theoretical = 0 lb/in^2**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	E-13		E-13		E-13		E-13	
5	E-12		E-12		E-12		E-12	
10	E-11		E-12		E-12		E-12	
20	E-11		E-11		E-12		E-11	
50	E-10		E-10		E-10		E-10	
100	E-10		E-10		E-10		E-10	
200			E-09		E-09		E-09	

Table B4-2

Random disorder of element shape - mesh size is 10 x 10  
 Thick plate: 0.20", stress free thermal expansion - 1.0 deg bulk temperature change

**Central point lateral displacement: theoretical = 2.000E-05 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.1	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.2	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.3	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.4	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.5	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.6	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.7	2.000000E-05	0.0%	2.000000E-05	0.0%	See Note 1		2.000000E-05	0.0%
0.8	See Note 1		2.000000E-05	0.0%	See Note 1		2.000000E-05	0.0%

**Max stress: theoretical = 0 lb/in^2**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	E-11		E-12		E-12		E-12	
0.1	E-12		E-12		E-12		E-12	
0.2	E-12		E-12		E-12		E-12	
0.3	E-12		E-12		E-12		E-12	
0.4	E-12		E-12		E-12		E-12	
0.5	E-12		E-12		E-12		E-12	
0.6	E-12		E-12		E-12		E-12	
0.7	E-12		E-12		See Note 1		E-12	
0.8	See Note 1		E-12		See Note 1		E-11	

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Table B4-3

Convergence study - increasing mesh size

Thick plate: 0.20", stress free thermal expansion - 1.0 deg temperature gradient through thickness

**Central point lateral displacement: theoretical = -2.000E-05 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
5	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
10	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
20	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
50	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
100	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
200			-2.000000E-05	0.0%	-2.000000E-05	0.0%	-1.999998E-05	0.0%

**Max stress: theoretical = 0 lb/in^2**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	E-12		E-13		E-13		E-13	
5	E-12		E-12		E-11		E-11	
10	E-11		E-11		E-10		E-11	
20	E-11		E-10		E-09		E-09	
50	E-10		E-10		E-07		E-07	
100	E-10		E-10		E-06		E-06	
200			E-09		E-04		E-05	

Table B4-4

Random disorder of element shape - mesh size is 10 x 10

Thick plate: 0.20", stress free thermal expansion - 1.0 deg temperature gradient through thickness

**Central point lateral displacement: theoretical = -2.000E-05 inches**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.1	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.2	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.3	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.4	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.5	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.6	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.7	-2.000000E-05	0.0%	-2.000000E-05	0.0%	See Note 1		-2.000000E-05	0.0%
0.8	See Note 1		-2.000000E-05	0.0%	See Note 1		-2.000000E-05	0.0%

**Max stress: theoretical = 0 lb/in^2**

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	E-11		E-11		E-10		E-11	
0.1	E-11		E-11		E-10		E-10	
0.2	E-11		E-11		E-10		E-10	
0.3	E-11		E-12		E-10		E-11	
0.4	E-11		E-12		E-10		E-10	
0.5	E-11		E-11		E-10		E-10	
0.6	E-11		E-11		E-10		E-10	
0.7	E-09		E-11		See Note 1		E-10	
0.8	See Note 1		E-11		See Note 1		E-10	

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)